The use of standardised runs (and associated data analysis) to monitor neuromuscular status in team sports players: a call to action

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Box to Box | Team sports | Monitoring

Headline

The increased occurrence of congested fixtures in professional team sports has amplified the need for player monitoring (1). While practitioners need to ensure players' readiness on a daily basis, match participation results in transient subjective, biochemical, metabolic and neuromuscular perturbations over hours and days (2,3). The current practice is therefore to assess players' neuromuscular status within 3 days following matches (1), which is aimed at giving practitioners the opportunity to adapt training content at the individual player level and in turn, improve performance and decrease injury risk (4).

The gold standard to measure neuromuscular function is the twitch interpolation technique (5) (Figure 1); this approach is however exclusively of use for research and is unfeasible within the team sports context (6). In the field, to have a global idea about player's neuromuscular status, jump variations are often used (e.g. counter movement jump, drop jump, hopping) (4). However, it is worth noting that in team sports force applications occur mainly horizontally, which suggests that the current (jump) methodology may lack sensitivity to monitor running-based specific neuromuscular status (7). Moreover, several practical challenges remain (e.g. time constraint within the microcycle, logistics, data analysis, testing intensity) making the assessment of neuromuscular status difficult in the context of team sports.

To overcome those challenges, standardised runs have been proposed as an alternative to jump variations as they can be easily implemented during training sessions on the pitch such as during warm-ups, with all players being tested at once. In fact, some of the accelerometer data collected during these runs have been proposed for the monitoring of neuromuscular status, due to their potential relationship with leg stiffness (8), which is itself affected by fatigue (9).

Aim

In this paper, the current methods to assess neuromuscular status using standardised runs (and the associated data analysis) are reviewed, and their possible integration into the programming puzzle is discussed.

Standardised runs (and associated data analysis): insights into the monitoring of neuromuscular status?

Micro technology systems, like GPS and embedded accelerometers, combined with computational methods of data processing, are opening up new opportunities and time efficient solutions to assess neuromuscular status (10). As fatigue has been shown to impair leg stiffness (9) and in turn, running mechanics, it was hypothesised that such fatigue-related impairments (11) may be reflected by change in the accelerometer activity (with the greater the reduction of the contribution of the vertical accelerometer vector to the overall magnitude vector, the greater the potential impairment in leg stiffness). Whilst the use of accelerometers during small sided-games (SSG) situations showed promising results (12) (i.e. decreased accelerometer activity during SSG when the jump data were indicative of neuromuscular fatigue), these approaches are unfortunately challenging to implement routinely due to several contextual factors (e.g. key players not available to train, congested fixtures minimising access to the drill of interest, rules, coaches' interventions, score line, drills used) (13,14). Consequently, the use of standardised runs has been suggested to have a better relevance, as in this scenario, external load can be controlled (i.e. speed and running distance). Nevertheless, before implementing a new methodology into practice, it is important to ascertain the validity, the reliability and the sensitivity of the test employed. To date, 4 studies have delved into the usefulness of standardised runs to monitor players' neuromusculars status. Those studies varied in terms of running bouts used (4x60m (7,13), 3x50m (15), 20m shuttle (16)), speed (22-24km.h-1 (7,15), 18km.h-1 (13), 12km.h-1 (16)), population (Soccer (7,16), Rugby Union (13), Australian rules (15)) and variables used (PlayerLoadTM (15,16), stride characteristics (7), running efficiency (7,13)). The different studies are summarised in Figure 2 and Table 1 and discussed throughout the following sections in terms of validity, reliability and sensitivity.

Validity

While the assumption that the (changes in) accelerometer activity performed during standardised runs is related to (changes in) leg stiffness have been widely spread (10), only one study directly assessed this relationship. In fact, we found a large (r=0.62) relationship between changes in a sort of running efficiency index (i.e. the ratio between vertical accelerometer activity and the actual speed during standardised runs, 4x60m performed in 12 s interspersed with 33 s of recovery), and changes in leg stiffness (i.e. assessed using a hopping test on force plates) (13). The absence of a stronger association between both indices could be explained by the different patterns of force application between the two measurements (i.e. vertical for hopping vs. horizontal for the standardised runs). Moreover, it is worth noting that this approach extrapolates mechanical variables (i.e. stride mechanics from accelerometer data) to estimate neuromuscular status (Figure 3). Consequently, several information could be lost throughout the process explaining the present results (Figure 3). As it stands, the validity of such approach is yet to be clearly established from a physiological and biomechanical standpoint. Several aspects

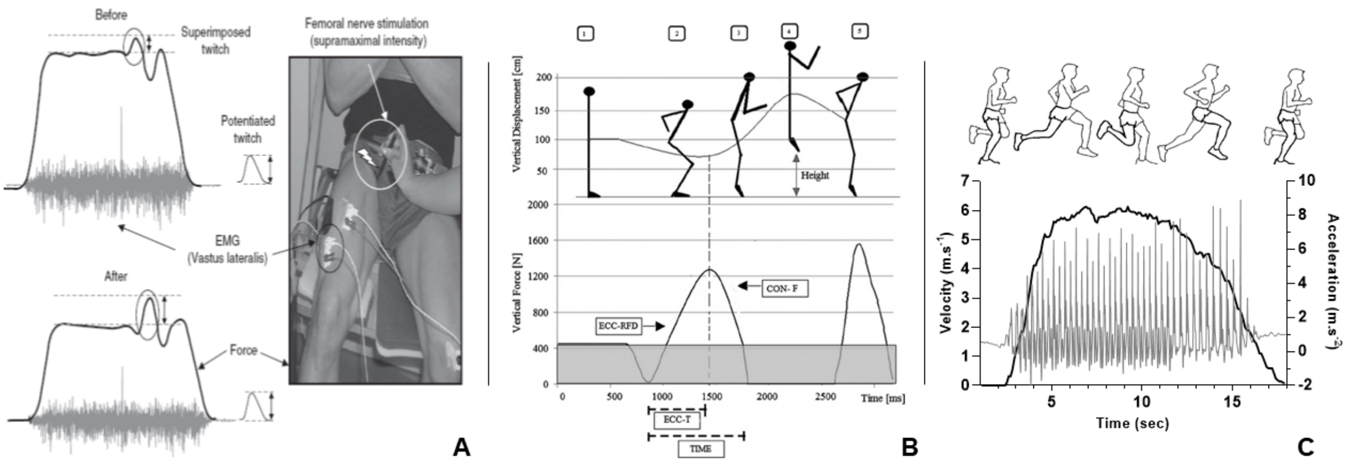

Fig. 1. Methods to explore neuromuscular function reproduced from Laursen and Buchheit (6) with permission. A: Twitch interpolation technique (lab only). B: Jumping assessment (field but lacking specificity); C: Standardised runs (likely optimal since pitch-based, time-efficient and specific in terms of force application).

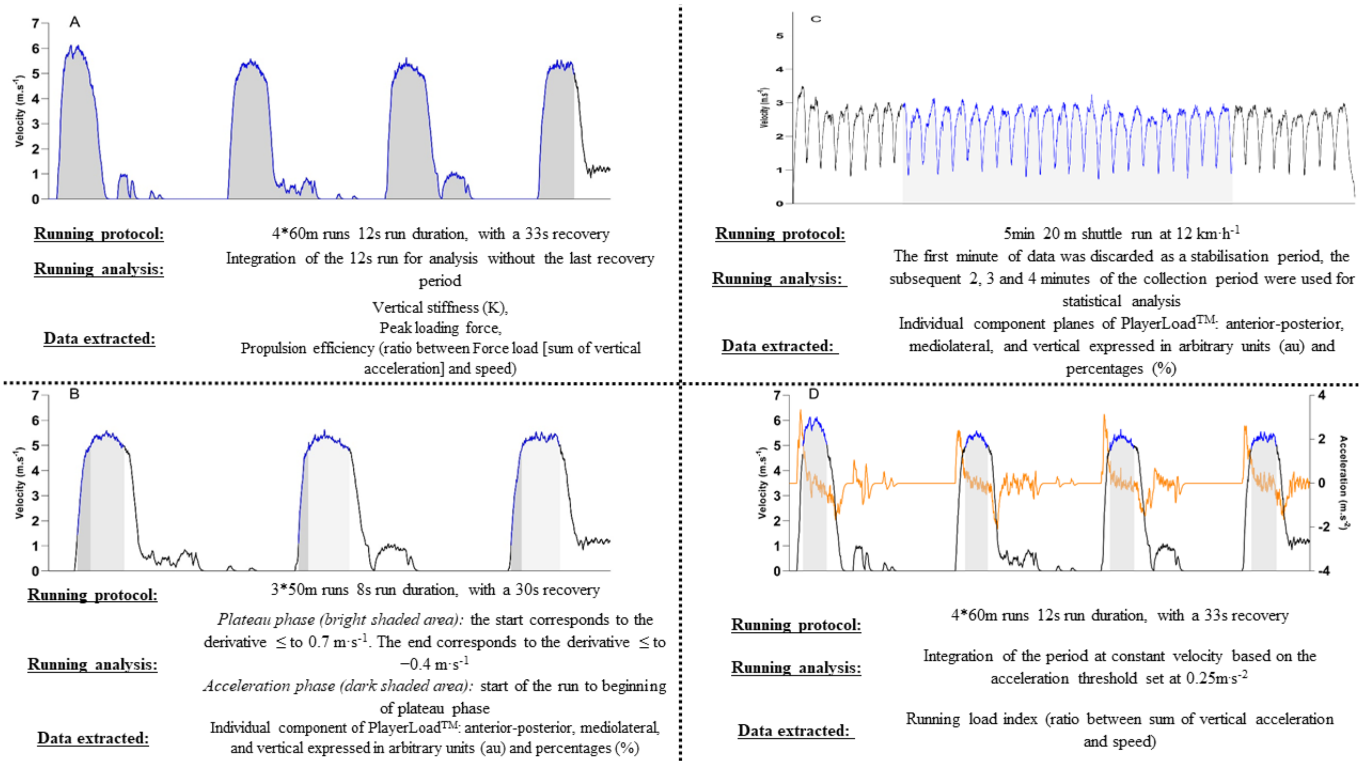

Fig. 2. GPS trace and method of data analysis during standardised runs. Tables represent the associated analysis used in each study. The blue line and the associated shaded area represent the portion of the run used for analysis. Figure A: Method used by Buchheit et al. (7). Figure B: Method used by Garrett et al. (15). Figure C: Method used by Fitzpatrick et al. (16). Figure D: Method used by Leduc et al. (13). Orange line in figure D represents the acceleration signal during the run.

must play a role in the accelerometer data responses during standardised runs (e.g. posterior chain strength and fatigue, running technique) and further investigations are required.

Reliability

Establishing the reliability is important before implementing a testing method within research or practice (17,18). All studies investigating the reliability of standardised runs employed different protocols and variables, making the comparison between studies difficult (Figure 2 and Table 1). Overall, those studies suggested that standardised runs (and the associated data analysis) are reliable to monitor neuromuscular status, with small-to-moderate standardised typical errors (for more details, see Table 1). While it seems that the reliability of standardised runs is poorer than that of traditional jump-based assessment (range of 2.1-17.1% vs. <5%), the cost-benefits and the practicality of these approaches (time-efficient, implementable in the field) is clearly in favour of the runs. Moreover, to improve reliability, and in turn, precision, practition-

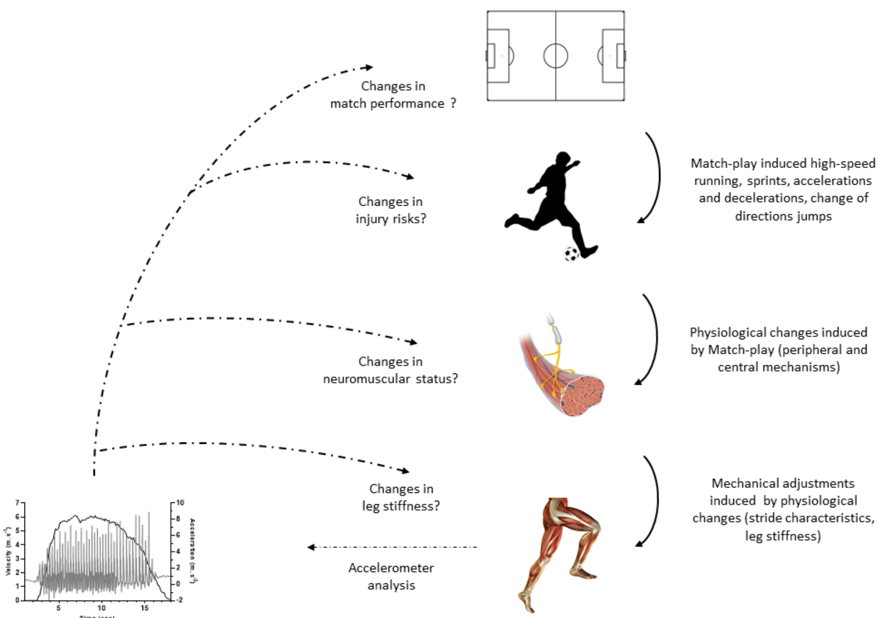

Fig. 3. Representation of the analysis process associated with standardised runs. Dashed lines represent potential links between accelerometer-related variables and players' physiology and stride mechanics.

ers can use more frequent assessments (the typical error decreases by a factor of $\sqrt{n}$ repetitions (19)).

Sensitivity

The sensitivity, referring as the ability of a test to correctly classify an individual status (20), has been assessed at different time scale and in diverse sport contexts (Table 1). In a group of AFL players, Garrett et al. (15) found the decline in the accelerometer activity to be concomitant to that of jump performance, confirming the potential of this method to monitor neuromuscular status. Furthermore, in their study, Buchheit et al. (7) observed a "propulsion efficiency index" (i.e. the ratio between accelerometer impulses and the actual running velocity) to be more sensitive to changes in neuromuscular status than estimated leg stiffness or peak impact force measures (moderate-to-large and trivial-to-small changes post-session, respectively). This potentially suggests that the use of running efficiency variables could capture more information about the neuromuscular status than leg stiffness *per se*. Moreover, the same method was sensitive enough to monitor improvements in neuromuscular efficiency occurring after a pre-season training camp in elite soccer players (21). Additionally, to allow meaningful decisions when using these data, practitioners need to consider the magnitude of usual changes in the accelerometer variables (signal) in relation to the observed typical error of measurement of the same variables (noise) (7), with the greater the signal-to-noise ratio, the greater the variable sensitivity. Except the variables tested by Garett et al. (21) (PlayerLoadTM medio-lateral, vertical and anterio-postirior) and Fitzpatrick et al. (16) (PlayerLoadTM total), which signal (smallest worthwhile change) was greater than its noise, most of the studies presented accelerometer variables with CVs superior to SWCs, suggesting that only moderate-to-large effect can be detected. Despite this limited signal-to-noise ratio, the cost/benefit of standardised runs are promising and should be considered in the context of team sports to assess neuromuscular status.

Potential future directions

Using standardised runs has numerous advantages when it comes to monitoring neuromuscular status. First, they are time-efficient compared with other jumping assessments performed on force plates or jump mats (5 min vs 1 h to perform for a full team). This approach would be particularly flexible as it can be employed in different contexts such as during 1) the post-match recovery period (Day+2-3 post-match), 2) the return to play process, 3) training camps (22) or 4) any moment of the season when a specific fitness assessment is required (Figure 4). Additionally, a better specificity (horizontal

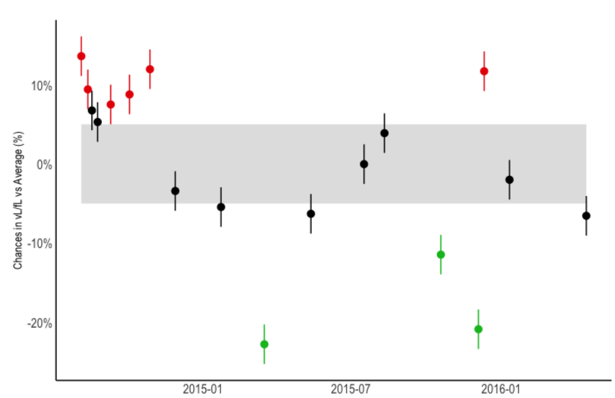

Fig. 4. A monitoring report obtained with standardised runs. vL/fL is the ratio between velocity load (vL) and force load (fL, obtained from the magnitude vector of the accelerometer, (10)). Values are expressed as changes compared with baseline (%). Red and green dots represent changes above or below the typical error and the smallest worthwhile change respectively. Black dots represent unclear change. Vertical bars represents the typical error expressed as coefficient of variation (%). Grey area represents the smallest worthwhile change. Note the variations in running efficiency throughout the years which likely represents players' neuromuscular status changes (i.e. fitness or fatigue) related to training load and match particiaption.

Authors	Population	Standardised Typical error	Typical error expressed as CV (%)[1]	SWC (%)[1]	Context of sensitivity analysis	Results	Proposed mechanisms
Buchheit et al., 2018	18 elite academy Soccer players	Small to moderate	11.0 – 17.1%	2.0 – 5%	Pre to immediately post different training sessions (strength, speed, endurance)	Small increase in K[2] after all session Large increase vL/fL[3] after strength session and small and moderate decrease after endurance and speed session respectively	Improvement in propulsion efficiency (less force Load on the ground for a similar motion activity) better intramuscular coordination or adjusting stride mechanics to explain the improvement in K and vL/fL Changes in horizontal force application capability resulting from large amounts of high-speed running to explain decrease in vL/fL
Garett et al., 2018	12 professional Australian football Rules	-	8.5 – 17.5%	1.0 – 7.0%	Post-game recovery kinetics (48h, 96h). Cluster between a fatigued and non-fatigued group based on 8% decrease in CMJ performance	Unclear to small changes in non-fatigued group at 48 and 96h Unclear to large changes in fatigued group at 48 and 96h	Increased ground-contact time, due to reductions in elastic recoil and associated energy used for vertical displacement leading to an increased knee flexion upon landing. This can be characterised by the adoption of the "Groucho" running patterns (reductions in vertical acceleration and is indicative of changes expected with reduced vertical stiffness)
Fitzpatrick et al., 2019	17 youth Soccer players	-	2.1 – 8.0%	1.1 – 2.8%	Pre to immediately, 24h and 48h post-training	Unclear differences immediately post-training Small to large differences at post 24h With Player Load (PL) medio-lateral and PL vertical in % presented the best signal: noise ratio Unclear differences at post 48h	Decreased peak ground reaction forces and lower extremity stiffness leading to a potential increase in step frequency
Leduc et al., 2020	17 University Rugby union players	Small to moderate	7.6 – 13.4%	2.6 – 5.2%	Pre to end of a training week	Trivial changes in leg Stiffness Large to very large increase in Running Load Index	Impairment of the posterior chain and the running mechanics induced by fatigue accumulated during training

Table 1: Reliability and sensitivity of standardised runs. 1: CV (coefficient of variation) and SWC (smallest worthwhile change) are presented as a range between the different indicators tested in each study. 2: K stands for leg stiffness. 3: vL/fL is the ratio between velocity load (vL) and force load (fL) obtained from the magnitude vector of the accelerometer.

vs. vertical force application) and player buy-in are generally observed (13).

However, several limits have to be acknowledged when using these tests to adjust training programs & recovery strategies for the subsequent day(s). More work is needed to clearly understand the relationship between changes in the observed variables (accelerometer data and the associated analytical indices) and the actual changes in strides mechanics and overall neuromuscular status (Figure 3). Additionality, as these runs need to be implemented during a field session (i.e. warm up), and since at the moment accelerometer data need to be computed post-session, training content and load can only be adjusted (if needed) for the following sessions. Live systems allowing the monitoring of these indices (and indirectly neuromuscular status) immediately during the standardised runs are therefore still required to allow on-pitch, within-session decision making. However, with the rapid enhancement of computing methods, the monitoring of neuromuscular status within session is now within reach (23–25). This would provide objective information about players' neuromuscular status at the end of each training session (or training sequence) and help practitioners to adjust training content on a daily basis. More research is still necessary to examine the benefit of this approach in terms of performance and injury risk.

Conclusion

Despite its large importance in terms of both performance and injury management, monitoring players' neuromuscular status in team sports remains both a theoretical and a practical challenge. However, thanks to micro technologies, time-efficient and running-specific solutions like standardised runs (and the associated data analysis) are emerging and can now be used to adjust training contents based on individual player's estimated neuromuscular status. Practitioners have nevertheless to be aware that until live data become available, both the complexity and time required to get some of the accelerometer data may limit their impact on practice (especially within day or within session). Consequently, it is important to continue the current research on how to accelerate the access to these data and better understand their relationship with physiological perturbation, strides mechanics, neuromuscular performance, fatigue and injury risk.

Practical Applications

- Standardised runs are likely more specific and more time-efficient than jump variations to monitor neuromuscular status in team sports.
- While the signal-to-noise ratio of the information obtained during standardised runs seems to be slightly poorer than that of traditional methods, the ease of their implementation allows for more frequent assessment which in turn, improves reliability and relevance.
- The relationship between changes in standardised runs derived-data and the underlining physiological factors affecting stride mechanics are yet to be fully understood.
- The development of live systems measuring neuromuscular status on the pitch will allow practitioners to make a great step forward in terms of player load individualisation.

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